Volume 8, Issue 1, January 2021 ISSN: 2348-8565 (Online)

IJMERT

International Journal of Modern Engineering and Research Technology

Website: http://www.ijmert.org Email: editor.ijmert@gmail.com

A Comparative Analysis of Voltage Satiability by Q-V Sensitive Analysis, and Line Index

Shubham Hirwane
M.Tech. Research Scholar
Energy Technology
Takshshila Institute of Engineering and Technology
Jabalpur, (M.P.) India
Email: shubhamhirwane13@gmail.com

Pramod Dubey
Assistant Professor
Electrical and Electronics & Engineering
Takshshila Institute of Engineering and Technology
Jabalpur, (M.P.) India
Email: pramoddubey@takshshila.org

ABSTRACT

Security of power systems operation is gaining ever increasing importance as the system operates closer to its thermal and stability limits. Power system stability–the most important index in power system operation may be categorized under two general classes relating to the magnitude and to the angle of bus voltages. Power system voltage stability involves generation, transmission and distribution from the voltage stability analysis point of view, system operators need to know not only the severity of their system, but also the mechanisms that cause voltage instability. This paper presents study of different methods and techniques used to improve the voltage stability of electrical power systems. Conventional P-V curve and Q-V curve methods are taken as a basic analysis tool.

Keywords:— *Voltage stability, Voltage Collapse, P-V Curve, Q-V curve, Line index.*

I. INTRODUCTION

Power transmission capability has traditionally been limited by either synchronous (or rotor angle) stability or by thermal loading capability of transmission line and equipment. Voltage stability is an important factor, which needs to be taken into consideration during the planning and operation of electrical power systems in order to avoid voltage collapse and subsequently partial or full system blackout. It mainly focuses on determining the proximity of bus voltage magnitudes to predetermined and acceptable voltage magnitudes whereas angle stability focuses on the investigation of voltage angles as the balance between supply and demand changes due to occurrences of a fault or disturbances in the system. Voltage stability is slowly varying phenomenon while angle stability is relatively faster and deals with systems dynamics described mathematically by differential equations of generators in the systems.

Voltage stability concerned with the ability of a power system to maintain acceptable voltages at all buses in the system under normal conditions and after being subjected to a disturbance. A power system at a given operating state is voltage stable if, following the disturbances; voltages near loads are identical or close to the pre-disturbance values. A power system is said to have entered a state of voltage instability when a disturbance results in a progressive and uncontrollable decline in voltage. Following voltage instability, a power system may undergo voltage collapse, if the post disturbance equilibrium voltages near loads are below acceptable limits. Voltage collapse is also defined as a process by which voltage instability leads to very low voltage profile in a significant part of the system. Voltage collapse may be total (blackout) or partial. The main cause of voltage collapse may be due to the inability of the power system to supply the reactive power or an excessive absorption of the reactive power by the system itself.

The present transmission network are getting more and more stressed due to economic and environmental constraints with growing size of power system networks, greater emphasis is being given to the study of voltage stability. The voltage stability can be studied either on static (slow time frame) or dynamic (long time frame) considerations [6, 8]. The static voltage stability methods are mainly depends on steady state model in the analysis, such as power flow model or a linearized dynamic model. Dynamic stability analysis describes the use of a model characterized by nonlinear differential and algebraic equations which include generators dynamics, tap changing transformers etc. Since the steady state analysis only involves the solution of algebraic equations it is computationally less extensive than dynamic analysis. Thus, lot of work is carried out to determine voltage stability on static analysis method. Several methods have been used in static voltage stability analysis such as the P-V and Q-V curves, model analysis, optimization method, continuation load flow method, etc.

In this paper, various methods for improving voltage stability have been studied and a two bus system has been investigated for the purpose of voltage stability of power system using one of the basic static analysis method- conventional P -V,Q-V curve method.

II. Power System Stability

Basic Concepts And Definitions

Power system stability may be defined as that property of a power system that enables it to remain in a state of operating equilibrium under normal operating conditions and to regain an acceptable state of equilibrium after being subjected to disturbances [10]. Traditionally the stability problem has been the rotor angle stability, i.e. maintaining synchronous operation. Instability may also occur without loss of synchronism in which case the concern is the control and stability of voltage. Power system is voltage stable if voltages after a disturbance are close to voltages at normal operating conditions. A power system becomes unstable when voltages uncontrollably decrease due to outage of equipment, increment of load, etc.

For good understanding of the stability problem, Power system stability is broadly classified as rotor angle stability-steady state stability and transient state stability, frequency stability and voltage stability-short term and long term voltage stability and it is load driven.

Voltage Stability and Rotor Angle Stability

Voltage stability and rotor angle stability are interlinked. Transient voltage stability is often interlinked with transient rotor angle stability, and slower forms of voltage stability are interlinked with small disturbance rotor angle stability. However, rotor angle stability as well as Voltage stability is affected by reactive power controls. Voltage stability is basically load stability and rotor angle stability is basically generator stability. It can be said that, if there is voltage collapse at a point in a transmission system remote from loads, it is an angle stability problem. If the voltage collapses in a load area it is probably mainly a voltage instability problem.

IV. Power System Voltage Stability

Voltage is considered as an integral part of power system and is considered as an important aspect in system stability and security. In recent years the problem of voltage instability got a considerable attention because of many voltage collapse incidents.

Basic Concepts of Voltage Stability

Voltage stability is the ability of a power system to maintain acceptable voltages at all buses in the system under normal conditions and after being subjected to a disturbance [11]. Power system is unstable when voltage decreases beyond particular limit because of outage of equipment, increase in load or decrease in controller's action. Voltage stability can be classified into two subclasses –

Large disturbance voltage stability: It is mainly concern with system ability to control voltage after large disturbance like system fault, loss of generators or circuit contingencies occur.

Small disturbance voltage stability: It is mainly concern with the system ability to control voltages following small disturbances like change in load.

Voltage Collapse

Voltage collapse typically occurs in power system which are usually heavily loaded, faulted and/or have reactive power shortages. Voltage collapse is system instability and it involves large disturbances (including rapid increase in load or power transfer) and mostly associated with reactive power deficits.

Voltage collapse is the process by which the sequence of events accompanying voltage instability leads to a low unacceptable voltage profile in a significant part of system. The main factors causing voltage instability are –

- The inability of the power system to meet demands for reactive power in the heavily stressed system to keep voltage in the desired range
- Characteristics of the reactive power compensation devices
- Action and Coordination of the voltage control devices
- Generator reactive power limits
- Load characteristics
- Parameters of transmission lines and transformer.

General Characterization of Voltage Collapse

Voltage collapse may be characterized as follows:

- The initiating event may be due to a variety of causes. Such as natural increase in system load or large sudden disturbances.
- The heart of the problem is the inability of the system to meet its reactive demands.
- The voltage collapse generally manifests itself as a slow decay of voltage.

Voltage collapse is strongly influence by the following significant factors as:

- Large distances between generation and load
- ULTC action during low voltage condition
- Unfavorable load characteristics
- Poor coordination between various control and protective system

The voltage collapse problem may be aggravated by excessive use of shun capacitor compensation.

IV. VOLTAGE STABILITY ANALYSIS

The analysis of voltage stability [10] for a given system state involves the examination of two aspects:

Proximity to voltage instability: How close is the system to voltage instability?

Mechanism of voltage instability: How and why does thus instability occur? What are the key factors contributing to instability? What are the voltage weak areas? What measures are most effective in improving voltage stability?

Voltage instability is a non linear phenomenon. It is impossible to capture the phenomenon as a closed form solution. There are various types of dynamics associated with the problems; hence many aspects of the problem can be effectively analyzed by using static as well as dynamic analyzing techniques. Following a disturbance, power simulations provide a method of study of a voltage instability problem. Two sets of graphs are used to study voltage instability. They are P-V curves and Q-V curves [7].

P-V Curve Analysis

The PV curves represent the voltage variation with respect to the variation of load reactive power. This curve is produced by a series of load flow solutions for different load levels uniformly distributed, by keeping constant the power factor. The generated active power is proportionally incremented to the generator rating or to the participating factors which are defined by the user. The P and Q components of each load can or cannot be dependant of the bus voltage accordingly to the load model selected. The determination of the critical point for a given load increment is very important because it can lead to the voltage collapse of the system. These characteristics are illustrated in figure 1.

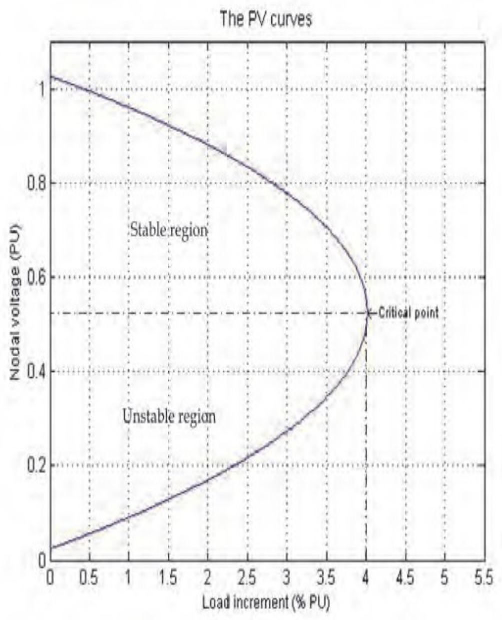


Figure 1 :P-V Curve

Q-V method

The V-Q curve method is one of the most popular ways to investigate voltage instability problems in power systems during the post transient period [2]. Unlike the P-V curve method, it does not require the system to be represented as two-bus equivalent. Voltage at a test bus or critical bus plotted against reactive power at that bus. A fictitious synchronous generator with zero active power and no reactive power limit connected to the test bus. The power-flow program run for a range of specified voltages with the test bus treated as the generator bus. Reactive power at the bus noted from the power flow solutions and plotted against the specified voltage. The operating point corresponding to zero reactive power represents the condition when the fictitious reactive power source removed from the test bus. Voltage security of a bus closely related to the available reactive power reserve, which can be easily found from the V-Q curve of the bus under consideration. The reactive power margin is the MVAR distance between the operating point and either the nose point of the V-Q curve or the point where capacitor characteristics at the bus are tangent to the V-Q curve [2]. Stiffness of the bus can be qualitatively evaluated from the slope of the right portion of the V-Q curve. The greater the slope is, the less stiff is the bus, and therefore the more vulnerable to voltage collapse it is. Weak busses in the system can be determined from the slope of V-Q curve. Voltage where dQ/dV becomes zero. If the minimum point of the V-Q curve is above the horizontal axis, then the system is reactive power deficient. Additional reactive power sources are needed to prevent a voltage collapse. In Figure 2.3, curves for p=1.00 and p=0.75 signify reactive power deficient busses. Busses having V-Q curves below the horizontal axis have a positive reactive power margin. The system may still be called reactive power deficient, depending on the desired margin for the simple two-bus system shown in figure 1, equations of V-Q curves for constant power loads can be derived as follows.. For a range of values of voltage and different active power levels, normalized V-Q curves are shown in figure 3. The critical point or nose point of the characteristics corresponds to the voltage where dQ/dV becomes zero. If the minimum point of the V-Q curve is above the horizontal axis, then the system is reactive power deficient. Additional reactive power sources are needed to prevent a voltage collapse. In Figure 1.2, curves for p=1.00 and p=0.75 signify reactive power deficient busses. Busses having V-Q curves below the horizontal axis have a positive reactive power margin. The system may still be called reactive power deficient, depending on the desired margin.

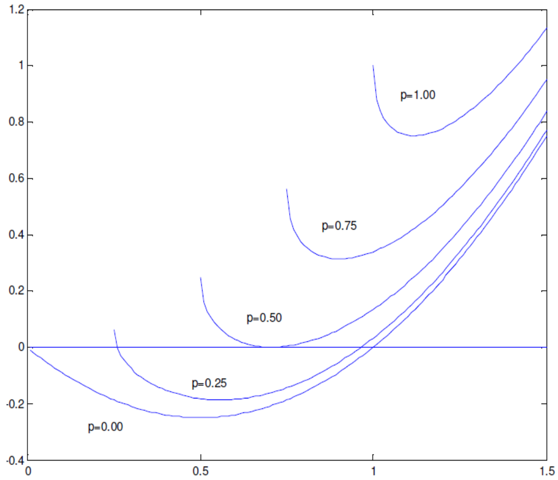
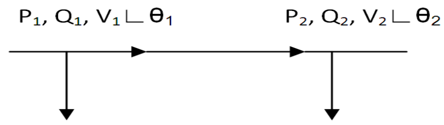


Figure 2: V-Q curves for the 2-bus test system

Voltage stability L-index

The mathematical formulation of the Voltage Stability *L*-index technique used in this paper is derived from voltage equations of a two bus network as shown in Figure1.Consider a line connecting two buses 1 and 2 where P1 and Q1 are the power injected into the line as shown above. The following equations can be derived.



Thus the L-Index is given by

$$L = \frac{4[V_1 V_2 \cos(\theta_1 - \theta_2) - V_2^2 \cos^2(\theta_1 - \theta_2)]}{V_1^2}$$

The value of L-index varies from 0 to 1.0. L -index value close to 0 indicates stable voltage condition while L-index value close to 1.0 indicates unstable voltage condition. In order to maintain a stable voltage condition in the system network, the value of L-index at any load bus must be kept to a small value close to 0. If the values of L-index at any load bus approaches 1.0, it shows that the load bus is close to its instability limit and if L-index is equal to 1.0. The system has already in the state of voltage collapse.

V. Results and Discussions

The proposed ANN based approach for voltage stability margin estimation is applied to IEEE 30 Bus system the load flow is done by newton rapsion method. The active power and reactive power loading are increased randomly from base case to full load and voltage stability margin are estimated by L-Index which is target vector for ANN [9]. The simulation results are given by figure 4 and 5. The available Simulation data were separated into 3 categories; training data and testing data and validation data. 60% data were used for the training process, while 20% data were utilized for the testing process and 20% data were utilized for the validation process. In the proposed technique, the training process was carried out many times until it meets a stopping criterion.

This work enhances the understanding of power systems network and voltage stability calculations. To analyze the power networks, a power-flow program is developed. It solves the power-flow problems of IEEE 6-bus system as shown in figure 3. The PV and Q-V curves are generated. It is found that the positioning of the device nearest to the weakest bus improves the Voltage of the weakest bus by a greater value than if it is placed at other position on the system.

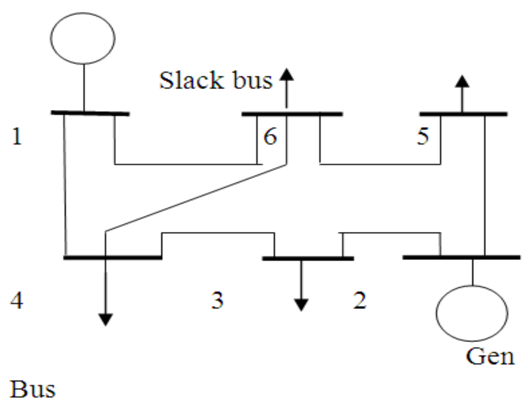


Figure 3: IEEE 6·bus test system

Result Obtained by L-Index Method

***Case-I**:* Increase loading of bus 3 from zero to the voltage collapse point, keeping the load at other buses fixed at the normal value. Observe the effect on index L (3) at bus 3.

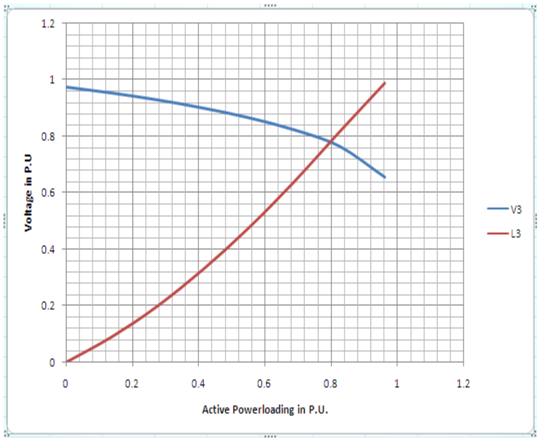


Figure 4: L-Index & Voltage characteristics at load bus 3.

The result which is showing in the figure 3 show the magnitude of bus voltage are decreases as loading are increased on the bus 3.Its conclude that the critical operating point L=0.9878, so the voltage stability of this system is guaranteed. The stability limit is reached for L=1.

Case-II: Increase loading of bus 3 from zero to the voltage collapse point, keeping the load at other buses fixed at the normal value. Observe the effect on index L (5) at bus 5.

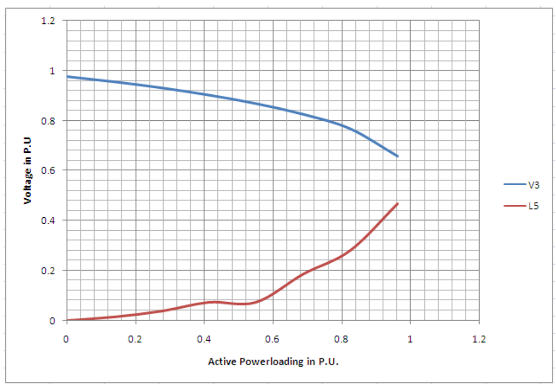


Figure 5: L-Index of bus 5 & Voltage characteristics at load bus 3.

The result which is showing in the Figure 4 show the magnitude of bus voltage v3 & corresponding the value of L=index at bus 5. The stability limit is reached at L=0.4677, because at the same time the voltage at bus 3, V3=0.657 is reached which critical limit for the system.

Case-III: Increase loading of bus 3 from zero to the voltage collapse point, keeping the load at other buses fixed at the normal value. Observe the effect on index L (6) at bus 6.

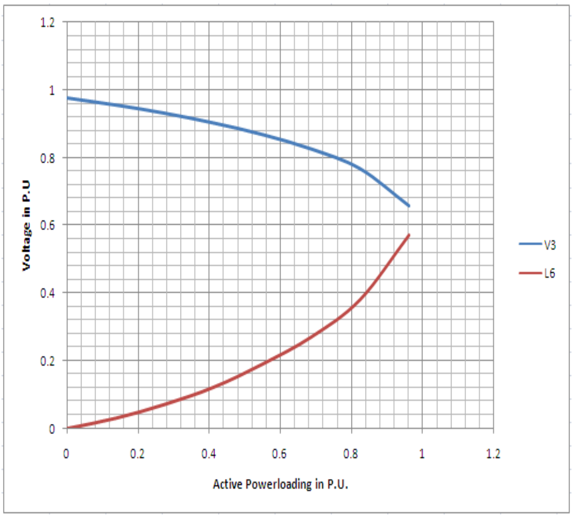


Figure 6: L-Index of bus 6 & Voltage characteristics at load bus 3.

The result which is showing in the Figure 5 show the magnitude of bus voltage v3 & corresponding the value of L-index at bus 5. The stability limit is reached at L=0.5705, because at the same time the voltage at bus 3, V3=0.657 is reached which critical limit for the system.

The voltage stability estimation methodology is tested on IEEE 6 bus system. In this paper, L-index method discussed is used to check the voltage stability of different load buses. The effect of loading at other load bus is assessed at increasing loading at bus no3 to neighboring buses connected to the bus under consideration the result are shown in Figure 6, 7, 8.

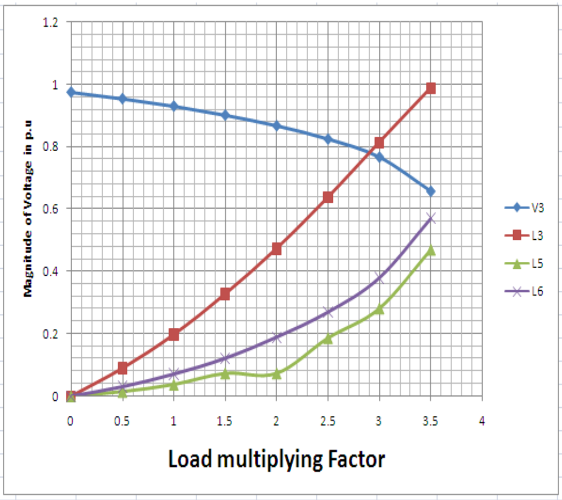


Figure 7: L-Index of bus 3, 5, 6 & Voltage characteristics at load bus 3.

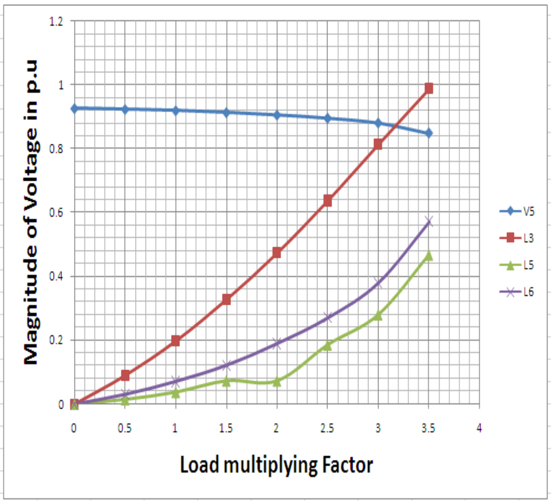


Figure 8: L-Index of bus 3, 5, 6 & Voltage characteristics at load bus 5.

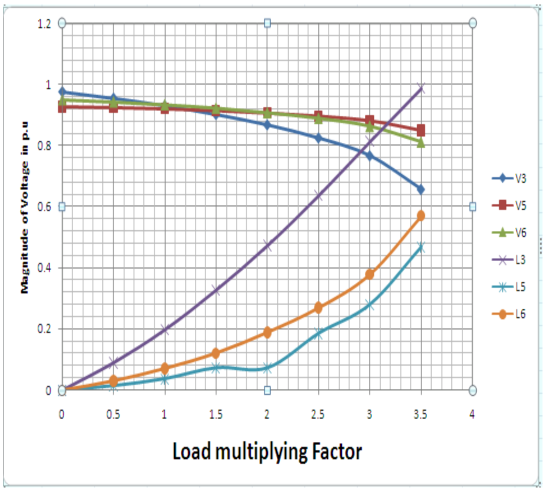


Figure 9: L-Index of bus 3, 5, 6 & Voltage characteristics at load bus 3, 5, 6.

Result Obtained by Q-V sensitive Analysis

QV curve is plotted by making load bus to pv bus, by specify constant active power and Q is vary step by step.

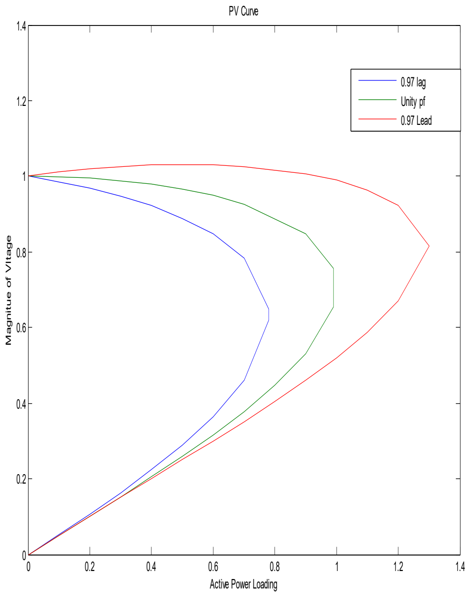


Figure 10: PV curve for different power factor

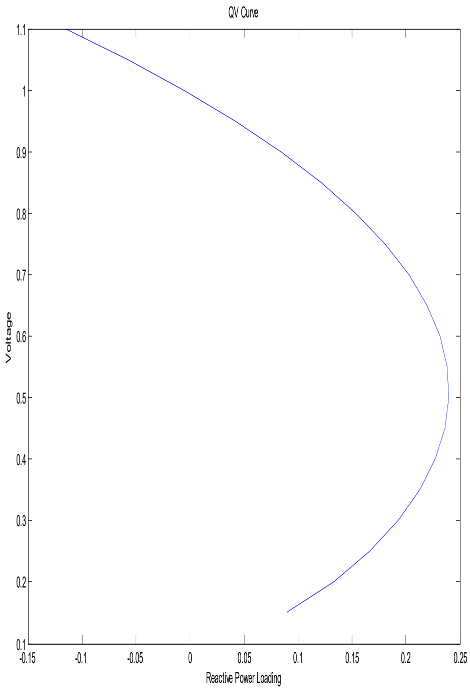


Figure 11: QV CURVE

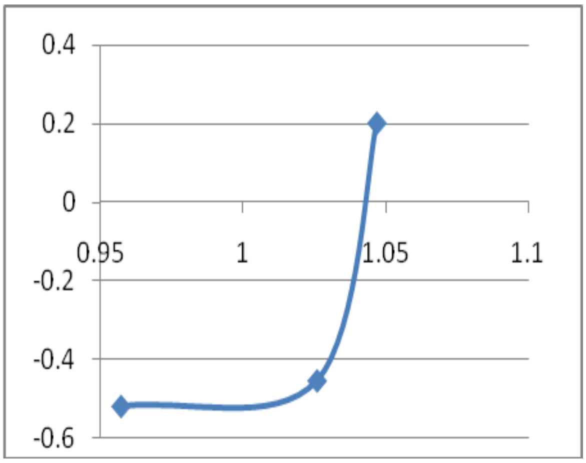


Figure 12: QV CURVE

VI. Conclusion

Simple analytical expression for real power and reactive power at receiving end and sending end of simple two bus system has been formulated and had been used to obtain voltage V2 at load point. The same voltage expression is used to draw P-V curve of a radial transmission line. It is observed that real power transfer increases from lagging to leading power factor. Using the Q-V curves the sensitivity of the load to the reactive power sources can be obtained. Thus basic voltage stability analysis tools i.e. P-V curve and Q-V curve are found to be effective tools to understand static voltage stability analysis. In L-index method The power systems are highly complex and working under heavily stressed conditions Therefore voltage stability has become one of the important issues in power system planning, operation and control. In this paper, the values of L-index are determine from IEEE 6-bus data, and the corresponding results in the form of L-index are calculated to know the closeness of current operating point to the critical point.

In this paper, L-indices have been calculated from IEEE 6-bus data. Give satisfactory solutions towards improved stability.

REFERENCES:

[1] AC Zambroni de Souza, Firtz Monn, Isabella F. Borges, "Using PV and QV Curves with the Meaning of Static Contingency Screening and planning," Electric Power System Research 81, 2011, pp. 1491-98.

[2] Arthit Sode, Yome, Nadarajah Mithulananthan and Kwand Y.Lee, "A Maximum Loading Margin Method for Static Voltage Stability in Power Systems," IEEE Trans. On Power Systems, Vol.21, No. 2, May 2006, pp. 799-808.

[3] Badru H. Chowdhury and Carson W.Taylor, "Voltage Stability Analysis-V-Q Power Flow Simulation versus Dynamic Simulation," IEEE Trans. On Power Systems, Vol.15, No.4, Nov. 2000, pp. 1354-1359.

[4] R. A. Schlueter, "A Voltage Stability Security Assessment Method," IEEE Trans. On Power Systems, Vol.13, No.4, Nov.1998, pp. 1423-1434.

[5] F. A. Althowibi and M.W.Mustafa, "Voltage Stability Calculations in Power Transmission Lines: Indications and Allocations," IEEE International Conference on Power and Energy, Nov.2010, pp. 390-395.

[6] P.Kessel and H.Glavitsch, "Estimating the Voltage Stability of a Power System" IEEE Transactions on Power Delivery, Vol. 1, No. 3, pp. 346–354, 1986.

[7] Asfar Ali Khan, "A Simple Method for Tracing P-V Curve of a Radial Transmission Line", World Academy of Science, Engineering and Technology 13 2008.

[8] Yang Zhang, Sidharth Rajagopalan, "Practical Voltage Stability Analysis," IEEE, 2010, pp. 1-7.

[9] Saffet Ayasun, Chika, Nwankpa, and Harry U. Kwatany, "Voltage Stability Toolbox for Power System Education and Research," IEEE Trans. On Education, Vol .90, No.4, Nov. 2006, pp. 432-442.

[10] Kundur P., Power Systems Stability and Control, McGraw-Hill, New York (1994) pp-959-1024.

[11] C.W.Taylor, Power System Voltage stability, Mc-Grawhill, 1993.

[12] Ali Keyhani1, Wenzhe Lu1, Gerald T. Heydt "Neural Network Based Composite Load Models for Power System Stability Analysis" IEEE International Conference on Computational Intelligence for Measurement Systems and Applications Giardini Naxos, Italy, pp 20-22 July 2005

[13] Geeta Negi, Anurag Kumar Swami, S. K. Goel & Ajay Srivastva "Assessment and Improvement of Voltage Stability using ANN Architecture" 7th WSEAS International Conference on Electric Power Systems, High Voltages, Electric Machines, Venice, Italy, pp 21-23, Nov.2007

* * * * *